

— Hermann Eoef,
With the Author's Compliments.

DIAMONDS.

A LECTURE

DELIVERED BEFORE THE

British Association, at Kimberley,

SEPTEMBER 5, 1905.

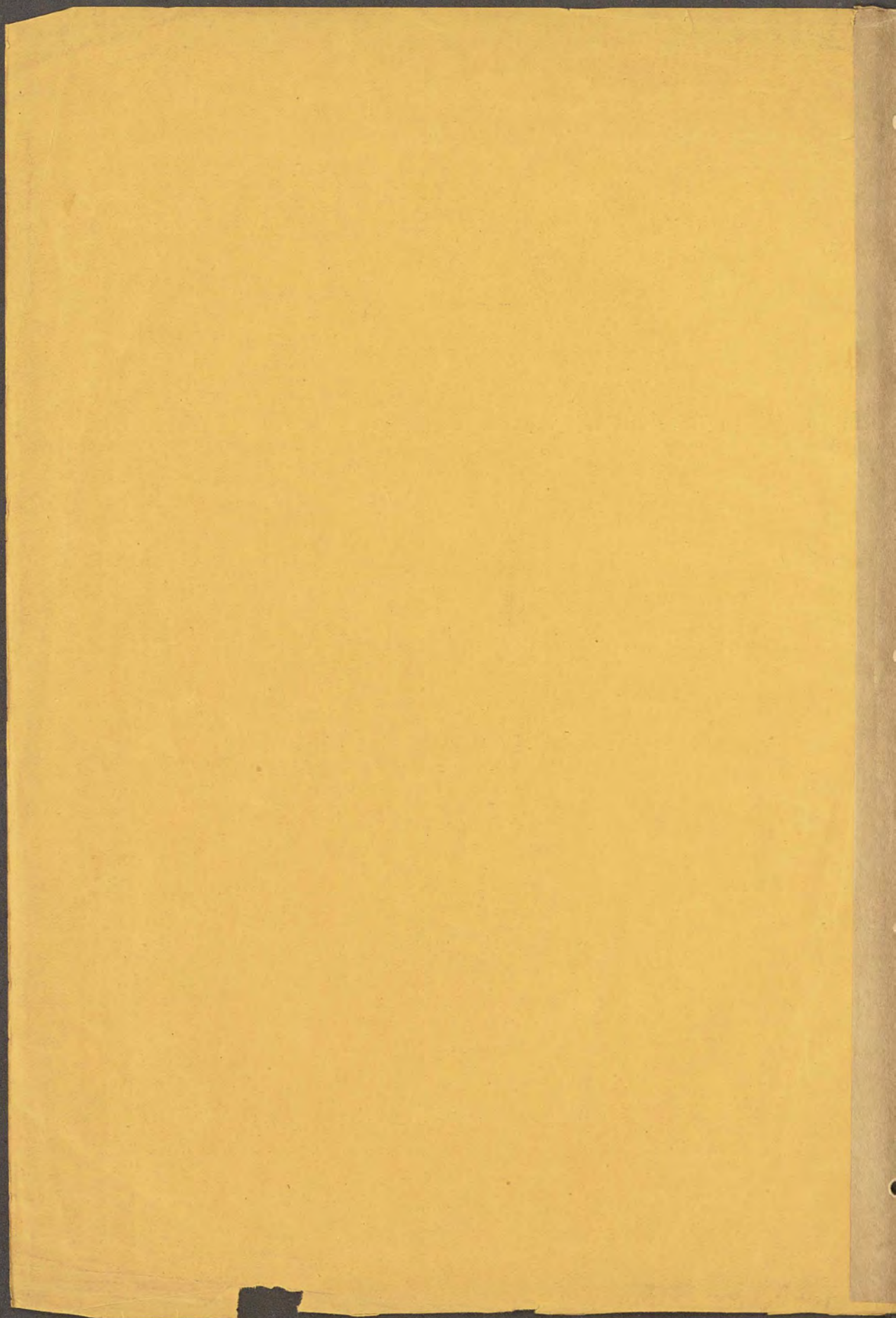
BY

SIR WILLIAM CROOKES,

Hon. D.Sc. (Oxford & Dublin), F.R.S.

LONDON.

1905.



Revised at Kimberley
Sept. 1905.

CORRIGIENDA.

Page 3, line 28. Alter paragraph as follows: "Diamonds from the 'river washings' are of a distinctive character and are quite unlike those from the 'dry mines.' They are of much better quality and the average size is considerably larger."

P. 4, l. 18. The pipes become narrower as the depth increases.

P. 4, l. 24. The present areas are:—

	Original Claims.	Open Mines.
Kimberley	... 10'37 acres.	37'23 acres.
De Beers	... 13'72 "	35'01 "
Dutoitspan	... 31'79 "	46'65 "
Bultfontein	.. 23'54 "	44'40 "
Wesselton	... 24'00 "	32'26 "

P. 4, l. 8 from bottom. The Dutoitspan Mine also was slightly elevated.

P. 7. Add to second footnote: "This portion of Africa must have been under water when the sandstone (now quartzite in places) was formed. Then the land must have risen above the water when the flow of lava, which formed the melaphyre, took place. It then sank again, and during the time of its being under water the shales were formed (assuming, of course, that the shales are of sedimentary formation)."

P. 9, l. 26. Instead of "Dutoitspan yields mainly coloured stones" read "Dutoitspan yields some fine blue-white stones, silver Capes and large yellow, and shows an exceptional proportion of large stones."

P. 12, l. 22. I am advised that my estimate of the honesty of the natives is too favourable.

P. 13, l. 33. For "400 to 450" read "250 to 400."

P. 29, ls. 5 to 9. The inference is too general. I have been shown diamond crystals which have irregular sides or faces.



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DIAMONDS.

IF ever a man felt the real inwardness of the saying, "Carrying coals to Newcastle," it is I, who audaciously stand before you this evening. My difficulties are three-fold. I have to address an audience thickly sprinkled with experts on a subject in which I am a mere graduate. I also have to address Members of the British Association, and if possible interest them in the wonderful development of an Industry which has made the few square miles in the centre of which we are standing the most valuable land on the face of the earth; and likewise I wish to illustrate the various properties of the diamond in a series of experiments few of which can be rehearsed beforehand,—as experiments sometimes destroy the stones,—and diamonds, as probably some present are aware, are expensive playthings.

From the earliest times the diamond has fascinated mankind. It has been a perennial puzzle—one of the "riddles of the painful earth." It is recorded in "Sprat's History of the Royal Society" (1667) that among the questions sent by order of the Society to Sir Philiberto Vernatti, Resident in Batavia, was one inquiring "Whether Diamonds grow again after three or four years in the same places where they have been digged out?" The answer sent back was "Never, Or at least as the memory of man can attain to."

In a lecture "On Diamonds," more than forty years ago,* Professor Maskelyne said :—"The diamond is a substance which transcends all others in certain properties to which it is indebted for its usefulness in the arts and its beauty as

* *Chemical News*, vol. i., p. 208.

an ornament. Thus, on the one hand it is the hardest substance found in nature or fashioned by art. Its reflecting power, and refractive energy, on the other hand, exceed those of all other colourless bodies, while it yields to none in the perfection of its pellucidity." He was constrained to add "The formation of the diamond is an unsolved problem."

Of late years the subject has fascinated many men of science. The development of electricity, with the introduction of the electric furnace, has facilitated research, and I am justified in saying that if the diamond problem is not actually solved, there is every probability it shortly will be solved.

South Africa, as I will show in detail, is the favourite haunt of diamonds on this planet; it ranks with Australia and California as one of the three great gold-yielding regions. But the wealth of South Africa is not limited to gold and diamonds. It is also the illimitable home of Coal—"the Black Diamond" of the Universe. The province of Natal alone contains more coal than Britain ever owned before a single bucket had been raised; and the coal beds extend into the Orange River Colony. Valuable iron ores exist also in large quantities.

In addition to these lavish natural riches the high grounds above Cape Town abound in medicinal health-giving waters. The districts where these springs occur are high lying, free from malaria, and admirably adapted for the restoration of invalids. It needs only some distinguished individual to set the fashion, some Emperor, Prince, or reigning Beauty to take the baths and drink the waters, and the tide of tourists will surely carry prosperity to Aliwal North, Fraserburg, Cradock, and Fort Beaufort.

It is to the Diamond industry I specially direct your attention to-night. I have studied diamonds scientifically for thirty years, and of the Kimberley mines I speak with the freshness of personal experience. In 1896, I spent nearly a month at Kimberley, when Mr. Gardner Williams General Manager of the De Beers Consolidated Mines, and the Managers of neighbouring mines, did their utmost to assist me in my enquiries and to aid me with valuable information. I had free access to all the workings, above and below ground, examined at leisure their stock and took extracts from their books. I had exceptional opportunities of studying the peculiar geological formation, and of noting facts connected with the birth of the precious stone which forms the subject of this evening's lecture.

Although my experiments are chiefly connected with the physical and chemical properties of diamonds, and with researches on the perplexities of their probable formation, it will be a kind of compensation for the dryness of some theoretical points, if with the help of a few photographs—taken on my former visit to South Africa—I bring before your eyes the general character of the mines and their surroundings.

The most famous diamond mines are Kimberley, De Beers, Dutoitspan, Bultfontein, and Wesselton. Kimberley is practically in the centre of the present diamond-producing area. The mines are situated in latitude $28^{\circ} 43'$ South, and longitude $24^{\circ} 46'$ East. There are also River Washings in the neighbourhood of the Vaal river, where the work is conducted in somewhat primitive fashion. When I was at Klipdam, miners had congregated at a spot called "New Rush," where some good finds of diamonds had been reported. At one of the claims where work was proceeding vigorously I asked the proprietor to let me be present at the sorting out. He willingly consented, but no diamonds were found. On my expressing regret, he said he had not seen a diamond for a fortnight! but then he had picked out one worth £300, "and that," he said, "will pay for several weeks' wages of my boys." This is the kind of speculative gambling that goes on at the river diggings. The miner may toil fruitlessly for months, and then luckily come across a pocket of stones, swept there by some eddy, by which he will net thousands. Diamonds from the "river washings" are of all kinds, as if contributed by every mine in the neighbourhood. They are much rolled and etched, and contain a fair proportion of stones of good quality, as if only the better and larger diamonds had survived the ordeal of knocking about. Besides these mines, there are in the Orange River Colony—about 60 miles from the Kimberley diamond region—two others of some importance known as Jagersfontein and Koffyfontein, whilst about 20 miles W.N.W. of Pretoria is situated the New Premier mine, now famous as the home of the wonderful "Cullinan" diamond.

KIMBERLEY.

The surface of the country round Kimberley is covered with a ferruginous red, adhesive, sandy soil, which makes traffic heavy. Below the red soil is a basalt, much decomposed and highly ferruginous, from 20 to 90 feet thick, and lower still from 200 to 250 feet of black slaty shale

containing carbon and iron pyrites. Then deeper a bed of conglomerate about 10 feet thick, and below the conglomerate about 400 feet of a hard compact rock of an olive colour, called "Melaphyre,"* or Olivine diabase. Below the melaphyre is a hard quartzite about 400 feet thick. The strata are almost horizontal, dipping slightly to the north; in places they are distorted and broken through by protruding dykes of trap. There is no water nearer than the Vaal river, about 14 miles away; formerly the miners were dependent on rain-water and a few springs and pools. Now, however, a constant and abundant supply of excellent water is served to the town. Good brick houses, with gardens and orchards, have sprung up on all sides.

THE PIPES.

The five diamond mines are all contained in a precious circle $3\frac{1}{2}$ miles in diameter. They are irregular shaped round or oval pipes, extending vertically downwards to unknown depths, retaining about the same diameter throughout. They are considered to be volcanic necks, filled from below with a heterogeneous mixture of fragments of surrounding rocks, and of older rocks such as granite, mingled and cemented with a bluish coloured hard clayey mass, in which famous blue clay the imbedded diamonds are hidden.

The areas of the mines are:—

Kimberley ...	...	...	33 acres
De Beers ...	...	...	22 "
Dutoitspan ...	...	...	45 "
Bultfontein ...	...	...	36 "

Before the discovery of the mines there was nothing in the superficial appearance of the ground to indicate the priceless treasures below. Since the filling of the volcanic ducts with diamantiferous ground, denudation has planed the surface; and the upper parts of the craters and other ordinary signs of volcanic activity being smoothed away, the superficial and ubiquitous red sand has covered and disguised the whole surface. The Kimberley mine seems to have presented a slight elevation above the surrounding flat country, while the sites of other mines were level or even slightly depressed.

Other diamantiferous pipes in the neighbourhood are small and do not contain stones in payable quantities. Hoards of diamonds may await the lucky discoverer, but where there are no surface signs, and the pipe itself is

* "MELAPHYRE. A waiting room for Rocks, till called for."

hidden under 10 or 20 feet of recent deposits, prospecting is a matter of sheer speculation. Hitherto accident has been the chief factor in the discovery of diamond mines.

How the great pipes were originally formed is hard to say. They were certainly not burst through in the ordinary manner of volcanic eruption, since the surrounding and enclosing walls show no signs of igneous action, and are not shattered or broken up even when touching the "blue ground." It is pretty certain these pipes were filled from below after they were pierced, and the diamonds were formed at some previous time and mixed with a mud volcano, together with all kinds of *débris* eroded from the rocks through which it erupted, forming a geological "plum pudding." The direction of flow is seen in the upturned edges of some of the strata of shale in the walls, although I was unable to see any upturning in most parts of the walls of the De Beers mine at great depths.

The breccia filling the mines, usually called "blue ground," is a collection of fragments of shale, and of various eruptive rocks, boulders, and crystals of many kinds of minerals. Indeed, a more wildly heterogeneous mixture can hardly be found anywhere else on this globe. The Kimberley mines for the first 70 or 80 feet are filled with so-called "yellow ground," and below that with "blue ground." This superposed yellow on blue is common to all the mines. The blue is the aboriginal ground, and owes its colour chiefly to the presence of lower oxides of iron. When atmospheric influences have access to the iron it becomes peroxidised, and the ground assumes a yellow colour. The thickness of yellow earth in the mines is therefore a measure of the depth of penetration of air and moisture. The colour does not affect the yield of diamonds. The ground mass is soapy to the touch, and friable, especially after exposure to weather. Besides diamonds, more than eighty species of minerals have been recognised in the blue ground, the most common being—Magnetite, ilmenite, garnet, bright green ferriferous enstatite (bronzite), a hornblendic mineral closely resembling smaragdite, calc-spar, vermiculite, diallage, jeffreysite, mica, kyanite, augite, peridot, iron pyrites, wollastonite, vaalite, zircon, chrome iron, rutile, corundum, apatite, olivine, sahlite, chromite, pseudobrookite, perofskite, biotite, and quartz.

The blue ground does not show any signs of igneous action; the fragments in the breccia are not fused at the edges. The eruptive force was probably steam or water-gas, acting under great pressure but at no high temperature.

There are many such pipes in the immediate neighbourhood of Kimberley. It may be that each volcanic pipe is the vent for its own special laboratory—a laboratory buried at vastly greater depths than we have yet reached—where the temperature is comparable with that of the electric furnace, where the pressure is fiercer than in our puny laboratories and the melting-point higher, where no oxygen is present, and where masses of liquid carbon have taken centuries, perhaps thousands of years, to cool to the solidifying point. The chemist arduously manufactures infinitesimal diamonds, valueless as ornamental gems; but Nature, with unlimited temperature, inconceivable pressure, and gigantic material, to say nothing of measureless time and appalling energy, produces without stint the dazzling, radiant, beautiful, coveted crystals I am enabled to show you to-night.

This hypothesis of the origin of diamonds is in many ways corroborated.

The ash left after burning a diamond invariably contains iron as its chief constituent; and the most common colours of diamonds, when not perfectly pellucid, show various shades of brown and yellow, from the palest "off colour" to almost black. They are also green, blue, pink, yellow, and orange. These variations give support to the theory advanced by Moissan that the diamond has separated from molten iron,—a theory of which I shall say more presently,—and also explain how it happens that stones from different mines, and even from different parts of the same mine, differ from each other. Further confirmation is given by the fact that the country round Kimberley is remarkable for its ferruginous character, and iron-saturated soil is popularly regarded as one of the indications of the near presence of diamonds. Along with carbon, molten iron dissolves other bodies which possess tinctorial powers. One batch of iron might contain an impurity colouring the stones blue, another lot would tend towards the formation of pink stones, another of green, and so on. Cobalt, nickel, chromium, and manganese, all metals present in the blue ground, would produce these colours.

An hypothesis, however, is of little value if it only elucidates half a problem. Let us see how far we can follow out the ferric hypothesis to explain the volcanic pipes. In the first place we must remember these so-called volcanic vents are admittedly not filled with the eruptive rocks, scoriaceous fragments, &c., constituting the ordinary contents of volcanic ducts.

A selection of thin sections of some of these rocks and minerals, mounted as microscopic objects and viewed by polarised light, are not only of interest to the geologist, but are objects of great beauty.

The appearance of shale and fragments of other rocks testify that the *mélange* has suffered no great heat in its present condition, and that it has been erupted from great depths by the agency of water vapour or some similar gas. How is this to be explained?

You will recollect I start with the reasonable supposition that at a sufficient depth* there were masses of molten iron at great pressure and high temperature, holding carbon in solution, ready to crystallise out on cooling. Far back in time the cooling from above caused cracks in superjacent strata through which water† found its way. On reaching the incandescent iron, the water would be converted into gas, and this gas would rapidly disintegrate and erode the channels through which it passed, grooving a passage more and more vertical in the necessity to find the quickest vent to the surface. But steam in the presence of molten or even red-hot iron liberates large volumes of hydrogen gas, together with less quantities of hydrocarbons‡ of all kinds—liquid, gaseous and solid. Erosion commenced by steam would be continued by the other gases; it would be easy for pipes, large as any found in South Africa, to be scored out in this manner.

Sir Andrew Noble has shown that when the screw stopper of his steel cylinders in which gunpowder explodes under pressure is not absolutely perfect, gas escapes with a rush so overpowering as to score a wide channel in the metal. Some of these stoppers and vents are on the table. To illustrate my argument Sir Andrew Noble has been kind enough to try a special experiment. Through a cylinder of granite is drilled a hole 0·2 inch diameter the size of a small vent. This is made the stopper of an explosion chamber, in which a quantity of cordite is fired, the gases escaping through the granite vent. The pressure is about 1500 atmospheres, and the whole time of escape is less than half a

* A pressure of fifteen tons on the square inch would exist not many miles beneath the surface of the earth.

† There are abundant signs that a considerable portion of this part of Africa was once under water, and a fresh-water shell has been found in apparently undisturbed blue ground at Kimberley.

‡ The water sunk in wells close to the Kimberley mine is sometimes impregnated with paraffin, and Sir H. Roscoe extracted a solid hydrocarbon from the "blue ground."

second. Notice the erosion produced by the escaping gases and by the heat of friction; these forces have scored out a channel more than half an inch diameter and melted the granite along their course. If steel and granite are thus vulnerable at comparatively moderate gaseous pressure, it is easy to imagine the destructive upburst of hydrogen and water-gas grooving for itself a channel in the diabase and quartzite, tearing fragments from resisting rocks, covering the country with *débris*, and finally, at the subsidence of the great rush, filling the self-made pipe with a water-borne magma in which rocks, minerals, iron oxide, shale, petroleum, and diamonds are violently churned in a veritable witch's cauldron! As the heat abated the water vapour would gradually give place to hot water, which forced through the magma would change some of the mineral fragments into the existing forms of to-day.

Each outbreak would form a dome-shaped hill; the eroding agency of water and ice would plane these eminences until all traces of the original pipes were lost.

Actions such as I have described need not have taken place simultaneously. As there must have been many molten masses of iron with variable contents of carbon, different kinds of colouring matter, solidifying with varying degrees of rapidity, and coming in contact with water at intervals throughout long periods of geological time—so must there have been many outbursts and upheavals, giving rise to pipes containing diamonds. And these diamonds, by sparseness of distribution, crystalline character, difference of tint, purity of colour, varying hardness, brittleness, and state of tension, have the story of their origin impressed upon them, engraved by natural forces,—a story which future generations of scientific men may be able to interpret with greater precision than is possible to-day.

The contents of the several pipes are not absolutely identical. The diamonds from each pipe differ in character, showing that the upflow was not simultaneous from one large reservoir below but the result of several independent eruptions. Even in the same mine there are visible traces of more than one eruption.

The blue ground varies in its yield of diamonds in different mines.

According to tables furnished by the De Beers Company, the yield of the De Beers and Kimberley mines has declined as the depth increases. At the same time the value of the stones has risen, and diamonds are more expensive to-day than at any previous time.

Year.			Number of carats* per load.†	Value per carat.	
				s.	d.
1889	...	...	1'283	19	8'75
1890	...	...	1'15	32	6'75
1891	...	...	0'99	29	6
1892	...	...	0'92	25	6
1893	...	...	1'05	29	0'6
1894	...	...	0'89	24	5'2
1895	...	...	0'85	25	6
1896	...	...	0'91	26	9'4
1897	...	...	0'92	26	10'6
1898	...	...	0'80	26	6'2
1899	...	...	0'71	29	7'2
1900	...	...	0'67	35	10'2
1901	...	...	0'76	39	7
1902	...	...	0'76	46	5'7
1903	...	...	0'61	48	6'3
1904	...	...	0'54	48	11'8

The diamonds from each mine have a distinctive character, and so uniform are the characteristics that an experienced buyer can tell at once the locality of any particular parcel of stones. De Beers and Kimberley mines are distinguished by the yield of large yellowish crystals with curved edges; Dutoitspan yields mainly coloured stones, while Bultfontein—half a mile off—produces small white octahedral crystals, occasionally speckled and flawed, but rarely coloured. The diamonds from the Wesselton mine are characterised by the large number of perfect octahedra of pure water amongst them. The diamonds from the Leicester mine have a frosted, etched appearance; they are white, the crystallisation

* According to Gardner Williams the South African carat is equivalent to 3'174 grains. In Latimer Clark's "Dictionary of Metric and other Useful Measures," the diamond carat is given as equal to 3'1683 grains = 0'2053 gramme = 4 diamond grains. One diamond grain = 0'792 troy grain. 151'5 diamond carats = 1 ounce troy.

Webster's "International Dictionary" gives the diamond carat as equal to 3 1/5th troy grains.

"The Oxford English Dictionary" says the carat was originally 1/144th of an ounce, or 3 1/3rd grains, but now equal to about 3 1/5th grains, though varying slightly with time and place.

The "Century Dictionary" says the diamond carat is equal to about 3 1/6th troy grains, and adds, that in 1877 the weight of the carat was fixed by a syndicate of London, Paris, and Amsterdam jewellers at 205 milligrammes. This would make the carat equal to 3'163 troy grains.

† A load weighs about 1600 lbs.

irregular ("cross-grained"), and they are hard and expensive to cut. Stones from Jagersfontein, in the Orange River Colony, display great purity of colour and brilliancy and they have the so-called "steely" lustre characteristic of old Indian gems.

Let me cite a description of a visit to Kimberley in 1872, by Mr. Paterson, who gives a graphic picture of the early days.

"The New Rush Diggings (as the Kimberley mine was first called) are all going forward in an oval space enclosed around by the trap dyke, of which the larger diameter is about 1000 feet, while the shorter is not more than 700 feet in length. Here all the claims of 31 feet square each are marked out with roadways about 12 feet in width, occurring every 60 feet. Upon these roadways, beside a short pole fixed into the roadway, sits the owner of the claim with watchful eye upon the Kaffir diggers below, who fill, and hoist by means of a pulley fixed to the pole above, bucketful after bucketful of the picked marl stuff in which the diamonds occur."

Soon came the difficulty how to continue working the host of separate claims without infringements. A system of rope haulage was then adopted. This mode of haulage continued in vogue during the whole of 1873, and if the appearance of the mine was less picturesque than when roadways existed, at least by moonlight it was a weird and beautiful sight.

But the mine was now threatened in two other quarters. The removal of the blue ground undermined the support from the walls of the pipe, and frequent falls of reef occurred, not only burying valuable claims but endangering the lives of workers below. Moreover, as the workings deepened, water made its appearance, necessitating pumping.

It soon became evident that open workings were doomed, and by degrees was devised the present system of underground working:

During this time of perplexity, individual miners who might have managed one or two claims near the surface could not continue work in the face of harassing difficulties and heavy expenses. Thus the claims gradually changed hands until the mine became the property first of a comparatively small number of capitalists, then of a smaller number of limited liability companies, until the whole of the mines have practically become the property of the "De Beers Consolidated Mines, Limited."

UNDERGROUND WORKINGS.

In the face of constant developments I can only describe the system in use at the time of my own visit—1896. Shafts are sunk in the solid rock at a sufficient distance from the pipe to be safe against reef movements in the open mine. In 1903, the rock shafts in the De Beers and Kimberley mines reached depths of 2076 and 2599 feet respectively. Tunnels are driven from these shafts at different levels, about 120 feet apart, to cross the mine from west to east. These tunnels are connected by two other tunnels running north and south, one near the west side of the mine and one midway between it and the east margin of the mine. From the east and west tunnels, offsets are driven to the surrounding rock. When near the rock, the offsets widen into galleries, these in turn being stoped on the sides until they meet, and upwards until they break through the blue ground. The fallen reef with which the upper part of the mine is filled sinks and partially fills the open space. The workmen then stand on the fallen reef and drill the blue ground overhead, and as the roof is blasted back the *débris* follows. When stoping between two tunnels the blue is stoped up to the *débris* about midway between the two tunnels. The upper levels are worked back in advance of the lower levels, and the works assume the shape of irregular terraces. The main levels are from 90 to 120 feet apart, with intermediate levels every 30 feet. Hoisting is done from only one level at a time through the same shaft. By this ingenious method every portion of blue ground is excavated and raised to the surface, the rubbish on the top gradually sinking and taking its place.

The scene below ground in the labyrinth of galleries is bewildering in its complexity, and very unlike the popular notion of a diamond mine. All below is dirt, mud, grime; half naked men, dark as mahogany, lithe as athletes, dripping with perspiration, are seen in every direction, hammering, picking, shovelling, wheeling the trucks to and fro, keeping up a weird chant which rises in force and rhythm when a greater task calls for excessive muscular strain. The whole scene is more suggestive of a coal mine than a diamond mine, and all this mighty organisation, this strenuous expenditure of energy, this costly machinery, this ceaseless toil of skilled and black labour, goes on day and night, just to win a few stones wherewith to deck my lady's finger! All to gratify the vanity of woman! "And," interposed a lady who heard this remark, "the depravity of man!"

With gems like diamonds, where fabulous riches are

concentrated into so small a bulk, it is not surprising that precautions against robbery are elaborate. The Illicit Diamond Buying (I.D.B.) laws are very stringent, and the searching, rendered easy by the "compounding" of the natives, is of the most drastic character. Formerly the favourite method of stealing diamonds was to swallow them, but when suspected, the personal inconveniences—in which certain powerful drugs took part—rendered this ingenious mode of stealing unpopular. It is, in fact, very difficult for a native employé to steal diamonds; were he to succeed, it would be almost impossible to dispose of them, as a potential buyer would prefer to secure the safe reward for detecting a theft rather than run the serious risk of doing convict work on the Cape Town Breakwater for a couple of years. I heard of a native who secreting a diamond worth several hundreds of pounds, after trying unsuccessfully to sell it, handed it back to the manager of his compound, glad to get the 6d. a carat to which he was entitled. Before the passing of the "Diamond Trade Act" the value of stolen diamonds reached nearly one million sterling per annum.

As a rule the better class of natives—the Zulus, Matabeles, Basutos, Bechuanas—when well treated, are honest and loyal. An amusing instance was told me of the devotion of a Zulu. He had been superintending a gang of natives on a small claim at the river washings near Klipdam. The claim yielded few stones, and the owner—my informant—sold the claim, handing over the plant and small staff, our friend the Zulu continuing to look after the business when the new man took possession. In the course of a few months the purchaser became dissatisfied with his bargain, not a single diamond having turned up since the transfer. Soon after this the Zulu came to his old master in a mysterious manner, and laying a handful of diamonds on the table, said "There, Baas, are your diamonds; I was not going to let the new man have any of them!"

DEPOSITING FLOORS.

Owing to the refractory character of blue ground fresh from the mines, it has to be exposed to atmospheric influences before it will pulverise under the action of water and mechanical treatment. It is brought to the surface and spread on the floors. Soon the heat of the sun and moisture produce a wonderful effect. Boulders, hard as ordinary sandstone when fresh from the mine, commence to crumble. At this stage the treatment of the diamonds assumes more the nature of farming than mining. To assist pulverisation by

exposing the larger pieces to atmospheric influences, the ground is frequently harrowed and occasionally watered. The length of time necessary for crumbling the ground preparatory to washing, depends on the season of the year and the amount of rain. The longer the ground remains exposed the better it is for washing. When the process is complete the softened friable blue clay is again loaded into trucks and taken to the washing machinery, where it is agitated with water and forced through a series of revolving cylinders perforated with holes about an inch in diameter; incorrigible lumps that will not pass the cylinders are again either subjected to the weathering process or passed between crushing rollers.

If a miner sees a diamond in a truck or in any of the blue ground in the mine, he has orders to secure it, and when he comes to the surface report it to the manager of the compound. If a white labourer, he is then credited with 3s. a carat, and if a black 6d. a carat. For a diamond found on the depositing floors about half these sums are paid.

WASHING AND CONCENTRATING MACHINERY.

The fine ground which has passed through the holes in the cylinder, together with a plentiful current of water, flows into the washing pans. These pans are of iron, 14 feet in diameter, furnished with ten arms, each having six or seven teeth. The teeth are set to form a spiral, so that when the arms revolve the teeth carry the heavy deposit to the outer rim of the pan, while the lighter material passes towards the centre and is carried from the pan by the flow of water. The heavy deposit contains the diamonds. It remains on the bottom of the pan and near its outer rim. This deposit is drawn off every twelve hours by means of a broad slot in the bottom of the pan. The average quantity of blue ground passed through each pan is from 400 to 450 loads in ten hours. The deposit left in each pan after putting through the above number of loads amounts to three or four loads, which go to the pulsator for further concentration.

THE PULSATOR.

The Pulsator is an ingeniously designed, somewhat complicated machine for dealing with the diamantiferous gravel already reduced one hundred times from the blue ground; the pulsator still further concentrating the gravel till the precious stones can be picked out by hand. The value of the diamonds in a load of original blue ground is about 30s., the gravel sent to the pulsator from the pans, reduced a hundred-fold, is worth £150 a load.

Mr. Fred Kirsten, an employé of the De Beer's Company,* made in 1897 the remarkable discovery that diamonds alone, of all minerals contained in the blue ground, adhere to grease, that all others will flow away as tailings over the end of the percussion table with the water. Now all the sorting (except for the very coarse size) is done by these machines, whose power of distinction is superior to the keenest eye of the native.

The diamond has a peculiar lustre, and on the sorter's table it is impossible to mistake it for any other stone. It looks somewhat like clear gum arabic, with a sort of intrinsic lustre which makes a conspicuous shine among the other stones.

Sometimes as many as 8000 carats of diamonds are separated in one day, representing about £10,000 in value.

About two million carats of diamonds are turned out of the Kimberley mines in a year, and by the end of 1904 ten tons of diamonds had come from these mines, valued at £60,000,000 sterling. This mass of blazing gems could be accommodated in a box five feet square and six feet high.

The diamond is a luxury for which there is only a limited demand. Ten years ago, from 4 to $4\frac{1}{2}$ millions sterling were spent annually in diamonds. The last few years there has been no necessity to restrict the supply, and at the mines of the De Beers Company there is no keeping pace with the demand.

Prodigious diamonds are not so uncommon as is generally supposed. Diamonds weighing over an ounce (151·5 carats) are not unfrequent at Kimberley. Nine years ago, in one parcel of stones I saw eight perfect ounce crystals, and one inestimable stone weighing two ounces. The largest diamond from the Kimberley mines weighed $428\frac{1}{2}$ carats, or nearly 4 ounces troy. It measured $1\frac{7}{8}$ inch through the longest axis, and was $1\frac{1}{2}$ inch square. After cutting, it weighed $228\frac{1}{2}$ carats, losing 200 carats in the process. The largest known diamond has recently been discovered at the New Premier mine, about 20 miles W.N.W. of Pretoria. This mine is of the same type as the Kimberley mines, but much larger in size, and in fact it is the largest known diamantiferous pipe in the world,—the pipe containing the "blue ground" along the longer diameter of its oval-shaped cross-section measuring over half a mile, the area of which is estimated at 350,000 square yards. This pipe breaks through felsitic rocks. The diamond, called "Cullinan" from the name of one of the directors of the Company on whose farm it was discovered, weighs no less than $3025\frac{3}{4}$ carats, or 9586·5 grains (1·37 lbs.

* Specification of G. Labram, of Kimberley, for "A Method and Apparatus for Separating Diamonds from Earthy Matters." 24,260/97.

avoiropois). It is a fragment, probably less than half, of a distorted octahedral crystal; the other portions still await discovery by some fortunate miner. Through this unequalled stone I passed a beam of polarised light in various directions, and could see colours in all cases, the brightest appearing when the light passed along the greatest diameter—about four inches. Here the colours were very fine, but no regular figure was to be seen. These observations show that the diamond is in a state of internal strain.

The clearness throughout is remarkable, the stone being absolutely limpid like water, with the exception of a few flaws, dark graphitic spots, and coloured patches close to the outside. At one part near the surface there is an internal crack, showing well the colours of thin plates. At another point there is a milky, opaque mass, of a brown colour, with pieces of what may be iron oxide. There are four cleavage planes of great smoothness and regularity. On other parts of the surface the crystalline structure is very marked. The edges are rounded in parts, and triangular markings (depressions) are to be seen. I also noticed square depressions, nearly as sharp and perfect as the triangular ones. Gigantic as is the Cullinan diamond, it represents in weight less than half the daily output of the De Beers mines, which averages about 7000 carats per day.

Next in size to the "Cullinan" comes the one which was found at the Jagersfontein mine. It weighed 970 carats—over half a pound.

I will show you on the screen the relative sizes of some large or famous diamonds.

1. Koh-i-noor, after the second cutting, 106 carats.
2. Loterie d'Angleterre, 49 carats.
3. Nizam of Hyderabad, 279 carats.
4. Orloff, 194 carats.
5. Koh-i-noor, after first cutting, 279 carats.
6. Regent or Pitt, 137 carats.
7. Duke of Tuscany, 133 carats.
8. Star of the South, 124 carats.
9. Pole Star, 40 carats.
10. Tiffany, yellow, 125 carats.
11. Hope, blue diamond, 44 carats.
12. Sancy, 53 carats.
13. Empress Eugenie, 51 carats.
14. Shah, 86 carats.
15. Nassak, 79 carats.
16. Pacha of Egypt, 40 carats.
17. The Cullinan, 3025 carats.
18. Excelsior, Jagersfontein, 969 carats.

THE DIAMOND OFFICE.

From the sorting room the stones are taken to the Diamond Office to be cleaned in acids and sorted into classes by the valuers, according to colour and purity. It is a sight for Aladdin to behold the valuers at work in the strong-room of the De Beer's Company. In the Kimberley treasure store the tables are literally heaped with stones won from the rough blue ground—stones of all sizes, purified, flashing, and of inestimable price; stones coveted by men and women all the world over; and last but not least stones that are destined to largely influence the development and history of a whole huge continent.

THE COMPOUND SYSTEM.

One great safeguard against robbery is the "compound" system of looking after the natives. A "compound" is a large square, about 20 acres, surrounded by rows of one-storey buildings of corrugated iron. These buildings are divided into rooms each holding about twenty natives. Within the enclosure is a Store where the necessaries of life are supplied at a reduced price, and wood and water free of charge. In the middle is a large swimming-bath with fresh water running through it. The rest of the space is devoted to games, dances, concerts, and any other amusement the native mind can desire. In case of accident or illness there is a well-appointed hospital where the sick are tended. Medical supervision, nurses, and food are supplied free by the Company.

In the compound are to be seen representatives of nearly all the picked types of African tribes. Each tribe keeps to itself, and to go round the buildings skirting the compound is an admirable object-lesson in ethnology. At one point is a group of Zulus; next we come to Fingoes; then Basutos; beyond come Matebele, Bechuanas, Pondos, Shangains, Swazis and other less known tribes, either grouped or wandering around making friendly calls.

The clothing in the compound is diverse and original. Some of the men are evident dandies, whilst others think that in so hot a climate a bright coloured handkerchief or "a pair of spectacles and a smile" is as great a compliance with the requirements of civilisation as can be expected.

The natives are not interfered with in their various amusements, always provided they do not make themselves objectionable to their neighbours. They soon learn that tribal animosities are to be left outside the compound. One Sunday afternoon my wife and I walked unattended about the

compound, almost the only whites present among 1700 natives. The manners of the fold were so friendly, and their smiles so cordial, that the idea of fear vanished. At one part a Kaffir was making a pair of trousers with a bright nickel-plated sewing-machine, in which he had invested his savings; next to him a "boy" was reading from the Testament in his own language to an attentive audience; in a corner a party were engaged in cooking a savoury mess in an iron pot; further on the orchestra was tuning up, and Zulus were putting the finishing touches to their toilet of feathers and beads. One group was intently watching a mysterious game. It is played by two sides, with stones, and grooves and hollows in the ground, and appears of most absorbing interest. It seems to be universal throughout Africa; it is met with among the ruins of Zimbabwe, and signs of it are recorded on old Egyptian monuments. I wanted to learn it, and an intelligent Zulu player offered to teach it to me in a few minutes. Captain Dallas, however, with a more accurate opinion of my sharpness than my friend the Zulu, assured me it would take months of study before I could begin to know anything about it. He had tried for years, and could make nothing of it.

They get good wages, varying according to occupation. The work is appreciated, and there are always more applicants than can be accepted. On entering, the restrictions to which they must submit are fully explained, and they are required to sign for three months at least, during which time they must not leave the compound or mine. It is seldom that a man does not return, once he has lived the life in the compound; some come again and again for years, only leaving occasionally to spend accumulated savings. The most careful men save money, and carry it at intervals to the superintendent to keep for them. Occasionally they ask to look at their savings, which may amount to £30 or £40, accumulated by dribblets. They are ignorant of savings banks or interest, and are content if they see their own money in the original rags and papers in which it was handed in. The Kaffir, on demand, must behold his coins just as he handed them in, wrappings and all. Sometimes the superintendent will have as much as £1000 of savings in his care.

GENESIS OF THE DIAMOND.

Speculations as to the probable origin of the diamond have been greatly forwarded by patient research, and particularly by improved means of obtaining high temperatures, an

advance we owe principally to the researches of Professor Moissan.

Until recent years carbon was considered absolutely non-volatile and infusible; but the enormous temperatures at the disposal of experimentalists—by the introduction of electricity—show that, instead of breaking rules, carbon obeys the same laws that govern other bodies. It volatilises at the ordinary pressure at a temperature of about 3600°C ., and passes from the solid to the gaseous state without liquefying. It has been found that other bodies, such as arsenic, which volatilise without liquefying at the ordinary pressure will easily liquefy if pressure is added to temperature. It naturally follows that if along with the requisite temperature sufficient pressure is applied, liquefaction of carbon will take place, when on cooling it will crystallise. But carbon at high temperatures is a most energetic chemical agent, and if it can get hold of oxygen from the atmosphere or any compound containing it, it will oxidise and fly off in the form of carbonic acid. Heat and pressure therefore are of no avail unless the carbon can be kept inert.

It has long been known that iron when melted dissolves carbon, and on cooling liberates it in the form of graphite. Moissan discovered that several other metals, especially silver, have similar properties; but iron is the best solvent for carbon. The quantity of carbon entering into solution increases with the temperature.

For the manufacture of—I am afraid I must say an infinitesimal—diamond, the first necessity is to select pure iron—free from sulphur, silicon, phosphorus, &c.,—and to pack it in a carbon crucible with pure charcoal from sugar. The crucible is then put into the body of the electric furnace, and a powerful arc formed close above it between carbon poles, utilising a current of 700 ampères at 40 volts pressure. The iron rapidly melts and saturates itself with carbon. After a few minutes heating to a temperature above 4000°C .—a temperature at which the iron melts like wax and volatilises in clouds—the current is stopped, and the dazzling fiery crucible is plunged beneath the surface of cold water, where it is held till it sinks below a red heat. As is well known, iron increases in volume at the moment of passing from the liquid to the solid state. The sudden cooling solidifies the outer layer of iron and holds the inner molten mass in a tight grip. The expansion of the inner liquid on solidifying produces an enormous pressure, and under the stress of this pressure the dissolved carbon separates out in transparent forms—minutely microscopic, it is true—all the same

veritable diamonds, with crystalline form and appearance, colour, hardness, and action on light the same as the natural gem.

Now commences the tedious part of the process. The metallic ingot is attacked with hot nitro-hydrochloric acid until no more iron is dissolved. The bulky residue consists chiefly of graphite, together with translucent chesnut-coloured flakes of carbon, black opaque carbon of a density of from 3.0 to 3.5, and hard as diamonds—black diamonds or carbonado, in fact—and a small portion of transparent colourless diamonds showing crystalline structure. Besides these, there may be carbide of silicon and corundum, arising from impurities in the materials employed.

The residue is first heated for some hours with strong sulphuric acid at the boiling point, with the cautious addition of powdered nitre. It is then well washed and for two days allowed to soak in strong hydrofluoric acid in cold, then in boiling acid. After this treatment the soft graphite disappears, and most if not all the silicon compounds have been destroyed. Hot sulphuric acid is again applied to destroy the fluorides, and the residue, well washed, is attacked with a mixture of the strongest nitric acid and powdered potassium chlorate, kept warm—but not above 60° C., to avoid explosions. This treatment must be repeated six or eight times, when all the hard graphite will gradually be dissolved, and little else left but graphitic oxide, diamond, and the harder carbonado and boart. The residue is fused for an hour in fluorhydrate of fluoride of potassium, then boiled out in water, and again heated in sulphuric acid. The well washed grains which resist this energetic treatment are dried, carefully deposited on a slide, and examined under the microscope. Along with numerous pieces of black diamond are seen transparent colourless pieces, some amorphous, others with a crystalline appearance. Although many fragments of crystals occur, it is remarkable I have never seen a complete crystal. All appear shattered, as if on being liberated from the intense pressure under which they were formed they burst asunder. I have singular evidence of this phenomenon. A fine piece of artificial diamond, carefully mounted by me on a microscopic slide, exploded during the night and covered the slide with fragments. Moissan's crystals of artificial diamond sometimes broke a few weeks after their preparation, and some of the diamonds which cracked weeks or even months after their preparation showed fissures covered with minute cubes. This bursting paroxysm is not unknown at the Kimberley mines.

On the screen I will project photographs of artificial diamonds manufactured in the manner described. So far, these specimens are all microscopic. The largest artificial diamond is less than one millimetre across.

These laboratory diamonds burn in the air before the blowpipe to carbonic acid. In lustre, crystalline form, optical properties, density, and hardness, they are identical with the natural stone.

In several cases Moissan separated ten to fifteen microscopic diamonds from a single ingot. The larger of these are about 0.75 m.m. long; the octahedra being 0.2 m.m.

GRAPHITE.

Intermediate between soft carbon and diamond come the graphites. The name graphite is given to a variety of carbon, generally crystalline, which in an oxidising mixture of chlorate of potassium and nitric acid forms graphitic oxide. This varies in colour from green to brown or yellow, or it is almost without colour, according to the completeness of the reaction. Graphites are of varying densities, from 2.0 to 3.0, and generally of crystalline aspect. Graphite and diamond pass insensibly into one another. Hard graphite and soft diamond are near the same specific gravity. The difference appears to be one of pressure at the time of formation.

Some forms of graphite exhibit the remarkable property by which it is possible to ascertain approximately the temperature at which they were formed, or to which they have subsequently been exposed. Sprouting graphite is a form, frequently met with in nature, which on moderate heating swells up to a bulky, very light mass of amorphous carbon. Moissan has found it in blue ground from Kimberley; my own results verify his. When obtained by simple elevation of temperature in the arc or the electric furnace graphites do not sprout; but when they are formed by dissolving carbon in a metal at a high temperature and then allowing the graphite to separate out on cooling, the sprouting variety appears. The phenomenon of sprouting is easily shown. I place a few grains in a test-tube and heat it to about 170° C., when you see the grains increase enormously in bulk and fill the tube with a light form of amorphous carbon.

The resistance of a graphite to oxidising agents is greater the higher the temperature to which it has previously been exposed. Graphites which are easily attacked by a mixture of fuming nitric acid and potassium chlorate are rendered more resistant by strong heat in the electric furnace.

BOILING- AND MELTING-POINT OF CARBON.

On the average the critical point of a substance is 1.5 times its absolute boiling point. Therefore the critical point of carbon should be about 5800° Ab. But the absolute critical temperature divided by the critical pressure is for all the elements so far examined never less than 2.5; this being about the value Sir James Dewar finds for hydrogen. So that, accepting this, we get the maximum critical pressure as follows, viz., 2320 atmospheres:—

$$\frac{5800^{\circ} \text{ Ab.}}{\text{CrP}} = 2.5, \text{ or } \text{CrP} = \frac{5800^{\circ} \text{ Ab.}}{2.5}, \text{ or } 2320 \text{ atmospheres.}$$

Carbon and arsenic are the only two elements that have a melting-point above the boiling-point; and among compounds carbonic acid and fluoride of silicium are the only other bodies with similar properties. Now the melting-point of arsenic is about 1.2 times its absolute boiling-point. With carbonic acid and fluoride of silicium the melting-points are about 1.1 times their boiling-points. Applying these ratios to carbon we find that its melting-point would be about 4400°.

Therefore, assuming the following data

Boiling-point	...	...	3870° Ab.
Melting-point	...	...	4400
Critical temperature	...	...	5800°
Critical pressure	...	...	2320 Ats.

the Rankine or Van der Waals formula calculated from the boiling-point and critical data would be as follows:—

$$\log. P = 10.11 - 39120/T,$$

and this gives for a temperature of 4400° Ab. a pressure of 16.6 Ats. as the melting-point pressure. The results of the formula are given in the form of a table:—

Temperature.	Pressure.	
Ab.	Ats.	
3870°	1.00	Boiling-point.
4000°	2.14	
4200°	6.25	
4400°	16.6	Melting-point.
4600°	40.4	
4800°	91.2	
5000°	193	
5200°	386	
5400°	735	
5600°	1330	
5800°	2320	Critical-point (15 tons per square inch).

If then we may reason from these rough estimates, above a temperature of 5800° Ab. no amount of pressure will cause carbon vapour to assume liquid form, whilst at 4400° Ab. a pressure of above 17 atmospheres would suffice to liquefy some of it. Between these extremes the curve of vapour pressure is assumed to be logarithmic, as represented in the accompanying diagram. The constant 39120 which occurs in the logarithmic formula enables us to calculate the latent heat of evaporation. If we assume the vapour density to be normal, or the molecule in vapour as C_2 , then the heat of volatilisation of 12 grms. of carbon would be 90,000 calories; or, if the vapour is a condensed molecule like C_6 , then the 12 grms. would need 30,000 calories. In the latter case the evaporation of 1 grm. of carbon would require 2500 calories, whereas a substance like zinc needs only about 400 calories.

A NEW FORMATION OF DIAMOND.

I have long speculated as to the possibility of obtaining artificially such pressures and temperatures as would fulfil the above conditions. In their researches on the gases from fired gunpowder and cordite, Sir Frederick Abel and Sir Andrew Noble obtained in closed steel cylinders pressures as great as 95 tons to the square inch, and temperatures as high as 4000° C. According to a paper recently communicated to the Royal Society, Sir Andrew Noble, exploding cordite in closed vessels, has obtained a pressure of 8000 atmospheres, or 50 tons per square inch, with a temperature reaching in all probability 5400° Ab.

Here, then, we have conditions favourable for the liquefaction of carbon, and were the time of explosion sufficient to allow the reactions to take place, we should certainly expect to get the liquid carbon to solidify in the crystalline state.*

By the kindness of Sir Andrew Noble I have been enabled to work upon some of the residues obtained in closed vessels

* Sir James Dewar, in a Friday Evening Discourse at the Royal Institution, 1880, showed an experiment proving that the temperature of the interior of a carbon tube heated by an outside electric arc was higher than that of the oxy-hydrogen flame. He placed a few small crystals of diamond in the carbon tube, and, maintaining a current of hydrogen to prevent oxidation, raised the temperature of the tube in an electric furnace to that of the arc. In a few minutes the diamond was transformed into graphite. At first sight this would seem to show that diamond cannot be formed at temperatures above that of the arc. It is probable, however, for reasons given above, that at exceedingly high pressures the result would be different.

after explosions, and I have submitted them to the same treatment that the granulated iron had gone through. After weeks of patient toil I removed the amorphous carbon, the graphite, the silica,* and other constituents of the ash of cordite, and obtained a residue among which, under the microscope, crystalline particles could be distinguished. Some of these particles, from their crystalline appearance and double refraction, were silicon carbide; others were probably diamonds. The whole residue was dried and fused at a good red heat in an excess of potassium bifluoride, to which was added during fusion 5 per cent of nitre. (Previous experiments had shown me that this mixture readily attacked and dissolved silicon carbide; unfortunately it also attacks diamond to a slight degree). The residue, after thorough washing and then heating in fuming sulphuric acid, was washed, dried, and the largest crystalline particles picked out and mounted. All the operations of washing and acid treatment were performed in a large platinum crucible by decantation (except the preliminary attack with nitric acid and potassium chlorate, when a hard glass vessel was used); the final result was washed into a shallow watch-glass and the selection made under the microscope.

I project on the screen a few photographs of these crystals. From the treatment they have undergone, chemists will agree with me that diamonds only could stand such an ordeal; on submitting them to skilled crystallographic authorities my opinion is confirmed. Speaking of the one before you (303), Professor Bonney calls it "a diamond showing octahedral planes with dark boundaries due to high refracting index." After careful examination, Professor Miers writes of the same crystal diamond:—"I think one may safely say that the position and angles of its faces, *and of its cleavages*, the absence of birefringence, and the high refractive index, are all compatible with the properties of the diamond crystallising in the form of an octahedron. Others of the remaining crystals, which show a similar high refractive index, appeared to me to present the same features."

It would have been more conclusive had I been able to get further evidence as to the density and hardness of the crystals; but I am still working at the subject, and hope to add these confirmatory tests. From what I have already said I think there is no doubt that in these closed vessel

* The silica was in the form of spheres, perfectly shaped and transparent, mostly colourless, but among them several of a ruby colour. When 5 per cent of silica was added to cordite, the residue of the closed vessel explosion contained a much larger quantity of these spheres.

explosions we have another method of producing the diamond artificially.

Sensational as is the story of the diamond industry in South Africa, quite another aspect fixes the attention of the chemist. The diamonds come out of the mines but how did they get in? How were they formed? What is their origin?

Gardner Williams, who knows more about diamonds than any man living, is little inclined to indulge in speculation. In his fascinating book* he frankly says:—

"I have been frequently asked, 'What is your theory of the original crystallisation of the diamond?' and the answer has always been, 'I have none; for after seventeen years of thoughtful study, coupled with practical research, I find that it is easier to "drive a coach and four" through most theories that have been propounded than to suggest one which would be based on any non-assailable data.' All that can be said is that in some unknown manner carbon, which existed deep down in the internal regions of the earth, was changed from its black and uninviting appearance to the most beautiful gem which ever saw the light of day."

METEORIC DIAMONDS.

Another diamond theory appeals to the fancy. It is said the diamond is a gift from Heaven, conveyed to earth in meteoric showers. The suggestion, I believe, was first broached by A. Meydenbauer,† who says:—"The diamond can only be of cosmic origin, having fallen as a meteorite at later periods of the earth's formation. The available localities of the diamond contain the residues of not very compact meteoric masses which may, perhaps, have fallen in prehistoric ages, and which have penetrated more or less deeply, according to the more or less resistant character of the surface where they fell. Their remains are crumbling away on exposure to the air and sun, and the rain has long ago washed away all prominent masses. The enclosed diamonds have remained scattered in the river beds, while the fine light matrix has been swept away."

According to this hypothesis, the so-called volcanic pipes are simply holes bored in the solid earth by the impact of monstrous meteors—the larger masses boring the holes, while the smaller masses, disintegrating in their fall, distributed diamonds broadcast. Bizarre as such a theory appears, I am bound to say there are many circumstances

* "The Diamond Mines of South Africa," p. 510: Macmillans, 1902.

† *Chemical News*, vol. lxi., p. 209, 1890.

which show that the notion of the Heavens raining diamonds is not impossible.

The most striking confirmation of the meteoric theory comes from Arizona. Here, on a broad open plain, over an area about five miles in diameter, have been scattered one or two thousand masses of metallic iron, the fragments varying in weight from half a ton to a fraction of an ounce. There is little doubt these masses formed part of a meteoric shower, although no record exists as to when the fall took place. Curiously enough, near the centre, where most of the meteorites have been found, is a crater with raised edges three-quarters of a mile in diameter and about 600 feet deep, bearing exactly the appearance which would be produced had a mighty mass of iron struck the ground and buried itself deep under the surface. Altogether ten tons of this iron have been collected, and specimens of the Canyon Diablo meteorite are in most collectors' cabinets.

An ardent mineralogist—the late Dr. Foote—cutting a section of this meteorite, found the tools were injured by something vastly harder than metallic iron. He examined the specimen chemically, and soon after announced to the scientific world that the Canyon Diablo meteorite contained black and transparent diamonds. This startling discovery was afterwards verified by Professors Moissan and Friedel, and Moissan, working on 183 kilogrammes of the Canyon Diablo meteorite, has recently found smooth black diamonds and transparent diamonds in the form of octahedra with rounded edges, together with green hexagonal crystals of carbon silicide. The presence of carbon silicide in the meteorite shows that it must, at some time, have experienced the temperature of the electric furnace. Since this revelation, the search for diamonds in meteorites has occupied the attention of chemists all over the world.

I am enabled to show you photographs of true diamonds I myself have extracted from the Canyon Diablo meteorite. A fine slab of the meteorite, weighing about seven pounds, is on the table before you.

Here, then, we have incontestible proof of the truth of the meteoric theory. Under atmospheric influences the iron would rapidly oxidise and rust away, colouring the adjacent soil with red oxide of iron. The meteoric diamonds would be unaffected, and left on the surface of the soil, to be found haphazard when oxidation had removed the last proof of their celestial origin. That there are still lumps of iron left at Arizona is merely due to the extreme dryness of the climate and the comparatively short time that the iron has been on

our planet. We are here witnesses to the course of an event which may have happened in geologic times anywhere on the earth's surface.

Although in Arizona, diamonds have fallen from the skies, confounding our senses, this descent of precious stones is what may be called a freak of Nature rather than a normal occurrence. To the modern student of science there is no great difference between the composition of our earth and that of extra-terrestrial masses. The mineral peridot is a constant extra-terrestrial visitor, present in most meteorites. And yet no one doubts that peridot is also a true constituent of rocks formed on this earth. The spectroscope reveals that the elementary composition of the stars and the earth are pretty much the same; and the spectroscope also shows that meteorites have as much of earth as of heaven in their composition. Indeed, not only are the selfsame elements present in meteorites, but they are combined in the same way to form the same minerals as in the crust of the earth.

It is certain from observations I have made, corroborated by experience gained in the laboratory, that iron at a high temperature and under great pressure—conditions existent at great depths below the surface of the earth—acts as the long-sought solvent for carbon, and will allow it to crystallise out in the form of diamond. But it is also certain, from the evidence afforded by the Arizona and other meteorites, that similar conditions have existed among bodies in space, and that on more than one occasion a meteorite freighted with jewels has fallen as a star from the sky.

Many circumstances point to the conclusion that the diamond of the chemist and the diamond of the mine are strangely akin as to origin. It is evident that the diamond has not been formed *in situ* in the blue ground. The genesis must have taken place at vast depths under enormous pressure. The explosion of large diamonds on coming to the surface shows extreme tension. More diamonds are found in fragments and splinters than in perfect crystals; and it is noteworthy that although these splinters and fragments must be derived from the breaking up of a large crystal, yet in only one instance have pieces been found which could be fitted together, and these occurred at different levels. Does not this fact point to the conclusion that the blue ground is not their true matrix? Nature does not make fragments of crystals. As the edges of the crystals are still sharp and unabraded, the *locus* of formation cannot have

been very distant from the present sites. There were probably many sites of crystallisation differing in place and time, or we should not see such distinctive characters in the gems from different mines, nor indeed in the diamonds from different parts of the same mine.

It is not difficult to imagine that masses of iron saturated with carbon existed formerly at a sufficient depth below the present mines, where temperature and pressure would produce the reactions which laboratory experiments show to be probable.

PHYSICS OF THE DIAMOND.

I will now briefly survey the chief chemical and physical characteristics of the diamond, showing you by the way a few experiments that bear upon the subject.

The black inclusions in some transparent diamonds consist of graphite. On crushing a clear diamond showing such spots and heating in oxygen to a temperature well below the point at which diamond begins to burn, Moissan found that the grey tint of the powder disappeared, no black spots being seen under the microscope. There also occur what may be considered intermediate forms between the well-crystallised diamond and graphite. These are "boart" and "carbonado." Boart is an imperfectly crystallised diamond, having no clear portions, and therefore useless for gems. Boart is frequently found in spherical globules, and may be of all colours. It is so hard that it is used in rock-drilling, and when crushed it is employed for cutting and polishing other stones. Carbonado is the Brazilian term for a still less perfectly crystallised form of carbon. It is equally hard, and occurs in porous masses, and in massive black pebbles, sometimes weighing a couple or more ounces.

CRYSTALLISATION.

The diamond belongs to the isometric system of crystallography; the prevailing form is octahedral. It frequently occurs with curved faces and edges. Twin crystals (macles) are not uncommon.

On the table I have models of various crystalline forms of native diamonds.

No. 20. Diamond in the form of a hexakis-octahedron (the forty-eight scalenohedron), or a solid figure contained by forty-eight scalene triangles. According to Professor Maskelyne, this occurs as a self-existent form only in the diamond.

No. 59. Diamond in the form of a hexakis-octahedron and octahedron. From Sudafrika.

No. 105. Diamond in the form of octahedron with intersections.

No. 127. Diamond from Brazil.

No. 128. Diamond from Sudafrika.

No. 129. Diamond from Brazil.

A macle or twin crystal, showing its formation from an octahedron with curved edges.

The use of diamond in glass cutting I need not dwell on. So hard is diamond in comparison to glass, that a suitable splinter of diamond will plane curls off a glass plate as a carpenter's tool will plane shavings off a deal board. On the screen I show a few diamond-cut glass shavings.

Many crystals of diamonds have their surfaces beautifully marked with equilateral triangles, interlaced and of varying sizes. Under the microscope these markings appear as shallow depressions sharply cut out of the surrounding surface; these depressions were supposed by Gustav Rose to indicate the probability that the diamonds at some previous time had been exposed to incipient combustion. Rose also noted that striations appeared on the surfaces of diamonds burnt before the blowpipe.

I have tried many times to imitate these markings by partial combustion of clear crystals of diamond, but have not succeeded in reproducing triangles of such beauty as you see formed by nature. According to the crystalline face exposed to incipient combustion the etchings are triangular or cubical, and sometimes intermediate between the two. I throw on the screen magnified photographs of these etchings, and you will observe that while the triangular or box like tendency is very apparent, there is an absence of regularity and sharpness.

The artificial markings are closer massed, looking as if the diamond during combustion had been dissected into triangular and rectangular flakes, while the markings natural to crystals appear as if produced by the crystallising force as they were being built up.

Certain artificial diamonds present the appearance of an elongated drop. I have seen diamonds which have exactly the appearance of drops of liquid separated in a pasty condition and crystallised on cooling. Diamonds are sometimes found with little appearance of crystallisation, but with rounded forms similar to those which a liquid might assume if kept in the midst of another liquid with which it would not mix. Other drops of liquid carbon retained for sufficient time above their melting-point would coalesce with adjacent drops, and on slow cooling would separate in the form of

large perfect crystals. Two drops, joining after incipient crystallisation, might assume the not uncommon form of interpenetrating twin crystals. Illustrations of all these caprices are here to-night.

Again, diamond crystals are generally perfect on all sides. They show no irregular side or face by which they were attached to a support, as do artificial crystals of chemical salts; another proof that the diamond must have crystallised from a dense liquid.

Having no double refraction the diamond should not act on polarised light. But as is well known, if a transparent body which does not so act is submitted to strain of an irregular character it becomes doubly refracting, and in the polariscope reveals the existence of the strain by brilliant colours arranged in a more or less defined pattern according to the state of tension in which the crystal exists. I have examined many hundred diamond crystals under polarised light, and with few exceptions all show the presence of internal tension. I will project some diamonds on the screen by means of the polarising microscope, and you will see by the colours how great is the strain to which some of them are exposed. On rotating the polariser, the black cross most frequently seen revolves round a particular point in the inside of the crystal; on examining this point with a high power, we sometimes see a slight flaw, more rarely a minute cavity. The cavity is filled with gas at enormous pressure, and the strain is set up in the stone by the effort of the gas to escape. I have already told you that the great Cullinan diamond by this means reveals a state of internal stress and strain.

It is not uncommon for a diamond to explode soon after it reaches the surface; some have been known to burst in the pockets of the miners or when held in the warm hand, and the loss is the greater because large stones are more liable to explode or fly in pieces than small ones. Valuable stones have been destroyed in this way, and it is whispered that cunning dealers are not averse to allowing responsible clients to handle or carry in their warm pockets large crystals fresh from the mine. By way of safeguard against explosion, some dealers imbed large diamonds in raw potato to insure safe transit to England.

The anomalous action which many diamonds exert on polarised light is not such as can be induced by heat, but it can easily be conferred on diamonds by pressure, showing that the strain has not been produced by sudden cooling but by sudden lowering of pressure.

The illustration of this peculiarity is not only difficult, but sometimes exceedingly costly—difficult because it is necessary to arrange for projecting on the screen the image of a diamond crystal between the jaws of a hydraulic press, the illuminating light having to pass through delicate optical polarising apparatus—and costly because only perfect, clear crystals can be used, and crystals of this character sometimes fly to pieces as the pressure rises. No colour as yet is seen on the screen, the crystal not being birefringent. A movement of the handle of the press, however, gives the crystal a pinch, instantly responded to by the colours on the screen, showing the production of double refraction. Another movement of the handle brightens the colours; a third may strain the crystal beyond its power of resistance, so I refrain.

HARDNESS.

Diamonds vary considerably in hardness, and even different parts of the same crystal differ in their resistance to cutting and grinding.

Beautifully white diamonds have been found at Inverel, New South Wales, and from the rich yield of the mine and the white colour of the stones, great things were expected. In the first parcel which came to England the stones were found to be so much harder than South African diamonds that it was at first feared they would be useless except for rock boring purposes. The difficulty of cutting them disappeared with improved appliances, and they now are highly prized.

The famous Koh-i-noor, when cut into its present form, showed a notable variation in hardness. In cutting one of the facets near a yellow flaw, the crystal became harder and harder the further it was cut, and after working the mill for six hours at the usual speed of 2400 revolutions a minute, little impression was made. The speed was increased to more than 3000, when the work slowly proceeded. Other portions of the stone were found to be comparatively soft, and hardened as the outside was cut away.

I can illustrate the intense hardness of the diamond by experiment. On the flattened apex of a conical block of steel I place a diamond, and upon it I bring down a second cone of steel. With the lamp I project an image of the diamond and steel faces on the screen, and force them together by hydraulic power. I can squeeze the stone into the steel blocks without injuring it in the slightest degree.

The pressure gauge shows (60) atmospheres, and the piston being 3·2 inches diameter, the absolute pressure is

(3·16) tons, equivalent on a diamond of (12) square m.m. surface to (170) tons per square inch of diamond.

Although not directly bearing on the subject I will introduce the only serious rival of the diamond as regards hardness. It is the metal tantalum, a fine specimen of which I owe to Messrs. Siemens Brothers. A hole had to be bored through a plate of this metal, and a diamond drill was used revolving at the rate of 5000 revolutions per minute. This whirling force was continued ceaselessly for three days and nights, when it was found that only a small depression $\frac{1}{4}$ m.m. deep had been drilled, and it was a moot point which had suffered most damage, the diamond or the tantalum.* In another respect tantalum is likely to rival graphitic carbon, as it has rivalled adamantine carbon. Its thin wire is extensively used for filaments of incandescent electric lamps; it shows a much higher efficiency than does the old carbon filament. The melting-point of tantalum is about 2300° C., a temperature seldom or never reached in an ordinary lamp.

DENSITY.

The following table gives the specific gravities of the minerals found on the sorting tables:—

	Specific gravity.
Hard graphite	2·5
Quartzite and granite	2·6
Beryl	2·7
Mica	2·8
Hornblende	3·0
Boart	3·47—3·49
Carbonado... ..	3·50
Diamond	3·514—3·518
Garnet	3·7
Corundum... ..	3·9
Zircon	4·4
Barytes	4·5
Chrome and titanite iron ore ...	4·7
Magnetite	5·0

I have here a liquid, the double nitrate of silver and thallium, which while solid at ordinary temperatures, liquefies at 75° C., and then has a specific gravity of 4·5. Admixture with water lowers the density to any desired point.

In the projection apparatus I have a glass cell containing this liquid diluted to a density of about 3·6. I throw in pieces of the above named minerals, and you see all those

* W. von Bolton, *Zeitschr. Elektrochem.*, ii., 45—51, Jan. 20, 1905.

whose density is lower than 3·6 rise to the surface, while the denser minerals sink. I now carefully add a little water and stir well, until I have reduced the density of the liquid to that of the diamond, when the heterogeneous collection sorts itself into three parts. The graphite, quartz, beryl, mica, and hornblende rise to the surface; the garnet, corundum, zircons, &c., sink to the bottom, while the diamonds float in the middle of the liquid. With a platinum landing net I skim off the swimmers and put them into one dish; with the same net I fish out the diamonds and put them in a second dish, while by raising a sieve at the bottom I remove the heavy minerals and put them into a third. The accurate separation of diamonds from the heterogeneous mixture has been effected in less time than has taken me to describe the experiment.

The table shows that diamonds vary somewhat in density among themselves, between narrow limits. Here is an illustration. I have a flat test-tube in which I have some of the same dense liquid, and in it are three selected diamonds. One rises to the top, another floats uncertain where to settle, rising and falling as I raise or lower the temperature of the sorting liquid, whilst the third sinks to the bottom. Allowing the liquid to cool a degree or two slightly increases the density and sends all three to the surface.

REFRACTIVITY.

But it is not the hardness of the diamond so much as its optical qualities that make it so highly prized. It is one of the most refracting substances in nature, and it also has the highest reflecting properties. In the cutting of diamonds advantage is taken of these qualities. When cut as a brilliant the facets on the lower side are inclined so that light falls on them at an angle of $24^{\circ} 13'$, at which angle all the incident light is totally reflected. A well cut brilliant should appear opaque by transmitted light except at a small spot in the middle where the table and culet are opposite. All the light falling on the front of the stone is reflected from the facets, and the light passing into the diamond is reflected from the interior surfaces and refracted into colours when it passes out into the air, giving rise to the lightnings, the effulgence, and coruscations for which the diamond is supreme above all other gems.

I hold some cut diamonds in the electric light; by transmitted light you see they are black, while by reflected light they fill the room with radiance, dazzle, and colour.

The following table gives the refractive indices of diamonds and other bodies:—

REFRACTIVE INDICES FOR THE D LINE.

Chromate of lead ...	2'50—2'97
Diamond	2'47—2'75
Phosphorus	2'22
Sulphur	2'12
Ruby	1'78
Thallium glass ...	1'75
Iceland spar	1'65
Topaz	1'61
Beryl	1'60
Emerald	1'59
Flint glass	1'58
Quartz	1'55
Canada balsam ...	1'53
Crown glass	1'53
Fluor-spar	1'44
Ice	1'31

In vain I have searched for a liquid of the same refraction as diamond. Such a liquid would be invaluable to the merchant, as on immersing a stone the clear body would absolutely disappear, leaving in all their ugliness the flaws and black specks so frequently seen even in the best stones.

Arguing from theoretical considerations connected with the Specific Refractive Energy of diamond, and employing Lorentz's expression for refraction—

$$\left(\frac{\mu^2 - 1}{\mu^2 + 2} \right) \left(\frac{P}{d} \right),$$

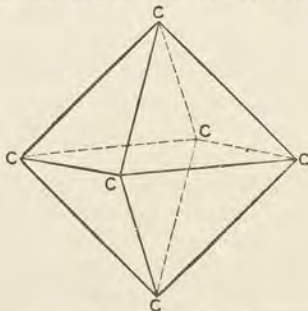
in which μ = refractive index;
 $\mu - 1$ = refractive energy;
 d = density;
 P = molecular weight.

Brühl has shown that diamond is perfectly normal in its optical properties, and has an atomic refraction = 5. He has put forward the speculation that the diamond may be the last member of the paraffin series of which marsh-gas is the first.

"Now we can imagine," says Brühl,* "why the diamond, *i.e.*, pure crystallised carbon, is optically normal. We obtain an idea of the mineral's chemical constitution, and of the way in which the atoms of carbon are perhaps combined in the sparkling gem. The diamond cannot possibly contain any double bonds. Imagine, however, at each of the six corners of a regular octahedron, a single molecule of marsh-gas,

* *Proceedings of the Royal Institution*, May 26, 1905.

CH_4 , *i.e.*, altogether C_6H_{24} , and then imagine all the 24 hydrogen atoms successively removed, so that each carbon atom is connected with each of its neighbours only by a single bond, and thus all six atoms of carbon are united together in a single whole. Then you obtain, as the most simple representation of the molecule of the diamond, a regular octahedron, with one atom of carbon at each of its six corners, whilst the edges represent the mutual bonds:—



Several simple molecules of this kind may be combined into one crystallised particle of the spectrochemically normal diamond."

ABSORPTION SPECTRUM OF DIAMOND.

On passing a ray of light through a diamond and examining it in a spectroscope, B. Walter has found in all colourless brilliants of over one carat in weight, an absorption band at wave-length 4155 (violet). He ascribes this band to an impurity and suggests it may possibly be due to samarium. Three other fainter lines were detected in the ultra-violet by means of photography.

PHOSPHORESCENCE OF DIAMOND.

After exposure for some time to the sun many diamonds glow in a dark room. Some diamonds are fluorescent, appearing milky in sunlight. In a vacuum, exposed to a high-tension current of electricity, diamonds phosphoresce of different colours, most South African diamonds shining with a bluish light. Diamonds from other localities emit bright blue, apricot, pale blue, red, yellowish green, orange, and pale green light. The most phosphorescent diamonds are those which are fluorescent in the sun. One beautiful green diamond in my collection, when phosphorescing in a good vacuum, gives almost as much light as a candle, and you can easily read by its rays. But the time has hardly come when diamonds can be used as domestic illuminants!

The emitted light is pale green, tending to white, and in its spectrum, when strong, can be seen bright lines, one at about λ 5370 in the green, one at λ 5130 in the greenish blue, and one at λ 5030 in the blue.

After many years' bombardment in a vacuum tube this diamond grew very dark, almost black on the surface. Heating in a mixture of nitric acid and potassium chlorate scarcely changed the colour. The action of heat was then tried, and on slowly heating to about 500° C. the dark colour entirely disappeared, and the original milky green appearance was restored. Although I watched narrowly I could see no trace of phosphorescence during the heating.

Diamonds which phosphoresce red generally show the yellow sodium line superposing on a continuous spectrum. In one Brazilian diamond phosphorescing a reddish yellow colour, I detected the citron line characteristic of yttrium.

By permission of Mrs. Kunz, wife of the well known New York mineralogist, I will show you perhaps the most remarkable of all phosphorescing diamonds. This prodigy diamond will phosphoresce in the dark for some minutes after being exposed to a small pocket electric light, and if rubbed on a piece of cloth a long streak of phosphorescence appears.

The rays which make the diamond phosphoresce are high in the ultra-violet. A thin sheet of glass cuts them all off. To illustrate this phosphorescence under the influence of the ultra-violet rays, I have arranged a powerful source of these rays, and in front I expose a design made up of certain minerals—willemite, franklinite, calcite, &c.,—phosphorescing of different colours. Their brilliant glow ceases entirely when I interpose a thin piece of glass between them and the ultra-violet lamp.

TRIBO-LUMINESCENCE.

A few minerals give out light when rubbed, and Mrs. Kunz's diamond is equally striking in this respect. In the year 1663 the Hon. Robert Boyle read a paper before the Royal Society, in which he described several experiments made with a diamond which markedly showed tribo-luminescence. As specimens of tribo-luminescent bodies I show you sphalerite (sulphide of zinc) and an artificial sphalerite, which is even more responsive to friction than the native sulphide.*

* Artificial tribo-luminescent sphalerite :—

Zinc carbonate	100 parts
Flower of sulphur	30 "
Manganese sulphate... ..	$\frac{1}{2}$ per cent

Mix with distilled water and dry at a gentle heat. Put in luted crucible and keep at a bright red heat for from two to three hours.

COMBUSTION OF THE DIAMOND.

When heated in air or oxygen to a temperature varying from 760° to 875° C. according to its hardness, the diamond burns with production of carbonic acid. It leaves an extremely light ash, sometimes retaining the shape of the crystal, consisting of iron, lime, magnesia, silica, and titanium. In boart and carbonado the amount of ash sometimes rises to 4 per cent, but in clear crystallised diamonds it is seldom higher than 0.05 per cent. By far the largest constituent of the ash is iron.

The following table shows the temperatures of combustion in oxygen of different kinds of carbon :—

	°C.
Condensed vapour of carbon	650
Carbon from sugar, heated in an electrical furnace	660
Artificial graphites, generally... ..	660
Graphite from ordinary cast-iron	670
Carbon from blue ground, of an ochrey colour	690
„ „ „ very hard and black	710
Diamond, soft Brazilian	760
„ hard Kimberley	780
Boart from Brazil	790
„ from Kimberley	790
„ very hard, impossible to cut	900

ACTION OF RADIUM ON DIAMOND.

The β -rays from radium having like properties to the stream of negative electrons in a radiant matter tube, it was of interest to ascertain if they would exert a like difference on diamond. The diamond glows under the influence of the β -radiations, and crushed diamond cemented to a piece of card or metal makes an excellent screen in a spinthariscopes—almost as good as zinc sulphide. Some fine colourless crystals of diamond were embedded in radium bromide and kept undisturbed for more than twelve months. At the end of that time they were examined. The radium had caused them to assume a beautiful blue colour, and their value as “fancy stones” had been materially increased. Here are a couple of diamonds originally of the same purity of water. One has been coloured by radium, the other is in its natural state. The colour of the radium tinted stone is very pronounced. The lantern slide shows the darkening thus produced. A and B are diamonds after twelve months burial in radium bromide; diamond C is of the original colour.

This blue colour is persistent and penetrates below the surface. It is unaffected by long continued heating in strong nitric acid and potassium chlorate, and is not discharged by heating to redness.

To find out if this prolonged contact with radium had communicated to the diamond any radio-active properties, six diamonds were put on a photographic plate, and kept in the dark for a few hours. I will project the image of the result after development. The three on the upper row are the diamonds which have had a prolonged sojourn with radium, the three below are similar diamonds picked out for comparison, which have not been near radium. See how strangely the three upper ones have acted. Notice also that by mere contiguity to the others the lower diamonds also shine with an induced, factitious radio-activity. I throw on the screen a magnified image of one of the blue crystals, and you see in how regular and geometrical a pattern the radio-active emanations radiate from the crystal. This observation has only been made a short time, and is still under investigation. Like the blue tint the radio-activity persists after drastic treatment. To me this proves that radio-activity does not merely consist in the adhesion of electrons or emanations given off by radium, to the surface of an adjacent body, but the property is one involving layers below the surface, and like the alteration of tint is probably closely connected with the intense molecular excitement the stone had experienced during its twelve months' burial in radium bromide.

A diamond that had been coloured blue by radium, and had acquired strong radio-active properties, was slowly heated to dull redness in a dark room. Just before visibility a faint phosphorescence spread over the stone. On cooling and examining the diamond it was found that neither the colour nor the radio-activity had suffered appreciably.

The diamond is remarkable in another respect. It is extremely transparent to the Röntgen rays, whereas highly refracting glass, used in imitation diamonds, is almost perfectly opaque to the rays. I exposed for a few seconds over a photographic plate to the X rays the large Delhi diamond of a rose-pink colour weighing $31\frac{1}{2}$ carats, a black diamond weighing 23 carats, and a glass imitation of the pink diamond. On development, the impression where the diamond obscured the rays was found to be strong, showing that most rays passed through, while the glass was practically opaque. By this means imitation diamonds can readily be distinguished from true gems.

I have already signified that there are various degrees of refractoriness to chemical reagents among the different forms of graphite. Some dissolve in strong nitric acid; other forms of graphite require a mixture of highly concentrated nitric acid and potassium chlorate to attack them, and even with this intensely powerful agent some graphites resist longer than others. M. Moissan has shown that the power of resistance to nitric acid and potassium chlorate is in proportion to the temperature at which the graphite was formed, and with tolerable certainty we can estimate this temperature by the resistance of the specimen of graphite to this reagent.

The superficial dark coating on a diamond after exposure to molecular bombardment I have proved to be graphite.* M. Moissan† has shown that this graphite, on account of its great resistance to oxidising reagents, cannot have been formed at a lower temperature than 3600° C.

It is thus manifest that the bombarding electrons endowed with an electric charge, and striking the diamond with enormous velocity, raise the superficial layer to the temperature of the electric arc, and turn it into graphite, whilst the mass of diamond and its conductivity to heat are sufficient to keep down the general temperature to such a point that the tube appears scarcely more than warm to the touch.

A similar action occurs with silver, the superficial layers of which can be raised to a red heat without the whole mass becoming more than warm.‡

I will now draw your attention to a strange property of the diamond, which at first sight might seem to discount the great permanence and unalterability of this stone. It has been ascertained that the cause of phosphorescence is in some way connected with the hammering of the electrons, violently driven from the negative pole, on to the surface of the body under examination, and so great is the energy of the bombardment, that impinging on a piece of platinum or even iridium, the metal will actually melt. When the diamond is thus bombarded in a radiant matter tube the result is startling. It not only phosphoresces, but assumes a brown colour, and when the action is long continued becomes almost black.

I will project a diamond on the screen and bombard it with radiant matter before your eyes. I do not like to

* *Chemical News*, vol. lxxiv., p. 39, July, 1896.

† *Comptes Rendus*, cxxiv., p. 653.

‡ *Proc. Roy. Soc.*, vol. l., p. 99, June, 1891.

anticipate a failure, but I am at the mercy of my diamond. I cannot rehearse this experiment, and it may happen that the diamond I have selected will show caprice and not blacken in reasonable time. Some diamonds visibly darken in a few minutes, while others, more leisurely in their ways, require an hour.

This blackening is only superficial, but no ordinary means of cleaning will remove the discolouration. Ordinary oxidising reagents have little or no effect in restoring the colour. The black stain on the diamond is due to a form of graphite which is resistant to oxidation.

CONVERSION OF DIAMOND INTO GRAPHITE.

Although we cannot convert graphite into diamond, we can change the diamond into graphite. I take a clear crystal of diamond and place it between two carbon poles, and throw the image on the screen by means of a powerful arc lamp behind. I now bring the poles with intervening diamond together and form an arc between. The temperature of the diamond rapidly rises, and when it approaches $3600^{\circ}\text{C}.$, the vaporising point of carbon, it breaks down, swells, and changes into black and valueless graphite. I show this experiment because it is striking and suggestive. I may add that it is costly—because the stone if not of fine quality might easily burst.

And now with this risky experiment my Address draws to a close. I hope I have given you some idea of the underground wonders of the Kimberley mines; my two visits have opened my own eyes. I have tried to picture the strenuous toil of the men who bring to the surface the buried treasures; and I have given you some idea of the skill and ingenuity with which their labours are controlled. I have also given you a sketch of the fiery origin of the diamond, of the glowing, molten, subterranean furnaces where they first take shape. I have shown you that a diamond is the outcome of a series of titanic convulsions, and that these precious gems undergo cycles of strange and potent vicissitudes before they can blaze on a ring or a tiara.

As to myself, I am glad we have made this second journey. I shall always recall with interest the dusky smiling natives at work and at play. And I am glad to have

seen that Arabian Nights vision, the strong-room of the De Beers Company, literally heaped with stones arduously won from the blue ground, purified, flashing, and of inestimable price. And, above all, I have vividly graven on my heart the friendly welcome, the innumerable acts of kindness, shown us by our able, energetic, and enterprising Colonial fellow countrymen.

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